



The Future of CubeSat Data Communications

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CubeSat Launches (1 of 3)

- Eurockot Launch (30 June 2003)
 - AAU1 CubeSat
 - DTU sat-1 (DOA)
 - CanX-1 (DOA)
 - Cute-1 (CO-55)
 - QuakeSat-1
 - XI-IV (CO-57)
- SSETI Express (27 Oct 2005)
 - XI-V (CO-58)
 - NCube-2 (DOA)
 - UWE-1
- M-V-8 Launch (22 Feb 2006)
 - Cute-1.7+APD (CO-56)
- Dnepr Launch 1 (26 July 2006)
(launch failure)
- Minotaur 1 (11 Dec 2006)
 - GeneSat-1 (2.4GHz)
- Dnepr Launch 2 (17 Apr 2007)
 - CSTB1
 - AeroCube-2
 - CP4
 - Libertad-1
 - CAPE1
 - CP3
 - MAST
- PSLV-C9 (28 Apr 2008)
 - Delfi-C3 (DO-64)
 - SEEDS-2 (CO-66)
 - CanX-2
 - AAUSAT-II
 - Compass-1
- Falcon Launch 1 (2 Aug 2008)
(launch failure)

Green = Amateur
Red = Experimental
Blue = Non-Amateur

CubeSat Launches (2 of 3)

- Minotaur-1 (19 May 2009)
 - AeroCube-3
 - CP-6
 - HawkSat-1 (DOA)
 - PharmaSat (2.4 GHz)
- ISILaunch 01 (23 Sep 2009)
 - BEESAT
 - UWE-2
 - ITUpSAT1
 - SwissCube
- Japanese H-IIA F17 (20 May 2010)
 - K-Sat
 - Waseda-SAT2
 - Negai Star
- PSLV-C15 (12 July 2010)
 - Tlsat-1
 - STUDSAT
- STP-S26 (19 Nov 2010)
 - RAX-1 (2.4 GHz)
 - O/ORES (2.4 GHz)
 - NanoSail-D2
- Falcon 9-002 (8 Dec 2010)
 - Perseus (4)
 - QbX (2)
 - SMDC-ONE
 - Mayflower (437 MHz)
- ELaNa-1/Taurus XL (4 Mar 2011)
 - (launch failure)
- PSLV-C18 (12 Oct 2011)
 - Jungu

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CubeSat Launches (3 of 3)

- ELaNa-3/NPP (28 Oct 2011)
 - M-Cubed
 - DICE (2)
 - Explorer-1' FU2
 - RAX-2 (2.4 GHz)
 - AubieSat-1
- Vega (20 Feb 2012)
 - Xatcobeo+
 - Robusta (DOA)
 - E-st@r (DOA)
 - Goliat
 - PW-Sat
 - MaSat-1
 - UniCubeSat (DOA)
- ELaNa-6/NROL-36 (13 Sep 2012)
 - SMDC-ONE (2)
 - AeroCube-4 (3)
 - Aeneas (437 MHz) (2.4 GHz)
 - CSSWE
 - CP5
 - CXBN
 - CINEMA
 - Re
- ISS (4 Oct 2012)
 - FITSat-1 (5.8 GHz)
 - TechEdSat
 - F-1
 - WE-WISH
 - RAIKO (13 GHz)

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TX Totals:
53 Amateur
18 Experimental
15 Non-Amateur

- 77 CubeSats delivered to orbit
- 19 CubeSats launched but failed to make orbit
- 7 CubeSats DOA
- 17 CubeSats decayed or deorbited

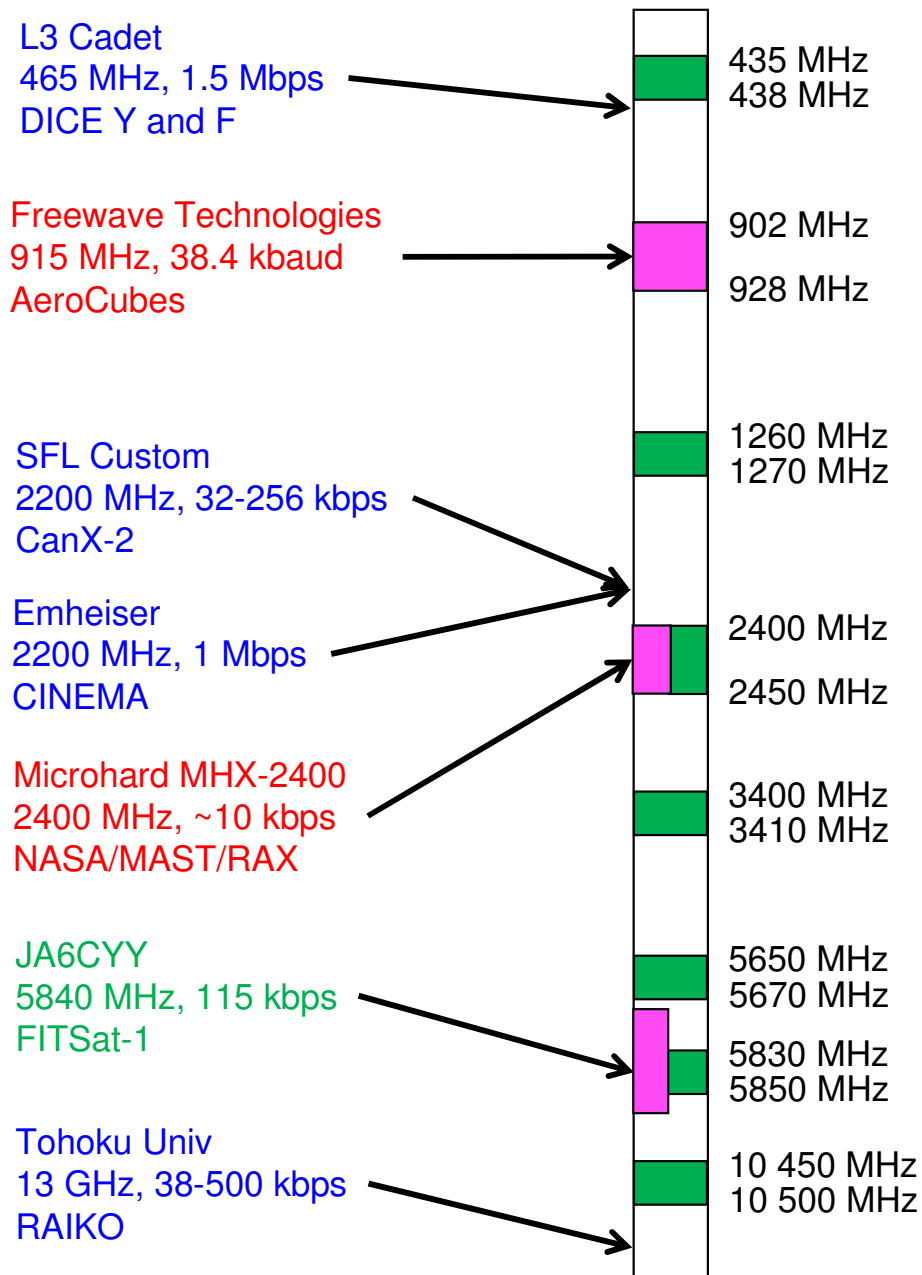
Two Classes of CubeSats

- Beginner CubeSats
 - New teams playing the “systems integrator” role
 - Educational mission with simple payload
 - VHF or UHF Amateur Radio frequencies due to ease of license and hardware
 - CP4, Libertad-1, HRBE
- High-Performance CubeSats
 - Established CubeSat teams or teams with existing satellite programs
 - Typically NSF or other US Government funded
 - Complex or expensive payload with high data rate requirements
 - Higher bandwidth requirements force higher frequency
 - RAX, DICE, CINEMA, QbX, AeroCube

Higher (than UHF) Frequency Satellites

- Are Amateurs interested in higher frequencies?
 - One group of Amateurs just want FM U/V
 - Another group wants HEO only
 - Another group wants microwave satellites
 - Higher frequencies are arguably more difficult/exotic/expensive
 - Evolution of communications
 - Yes, there is interest in higher frequencies
- Is the CubeSat community interested in higher frequencies?
 - 44 of 77 CubeSats are VHF/UHF Amateur Radio only
 - 56 transmitters in VHF/UHF Amateur Radio bands
 - Beep-sats will probably always use UHF Amateur Radio
 - CubeSats put into small slice of spectrum, other users (voice) protected
 - Higher performance satellites will go higher (to other services)
 - Yes, there is interest in higher frequencies

Higher (than UHF) Frequency CubeSats



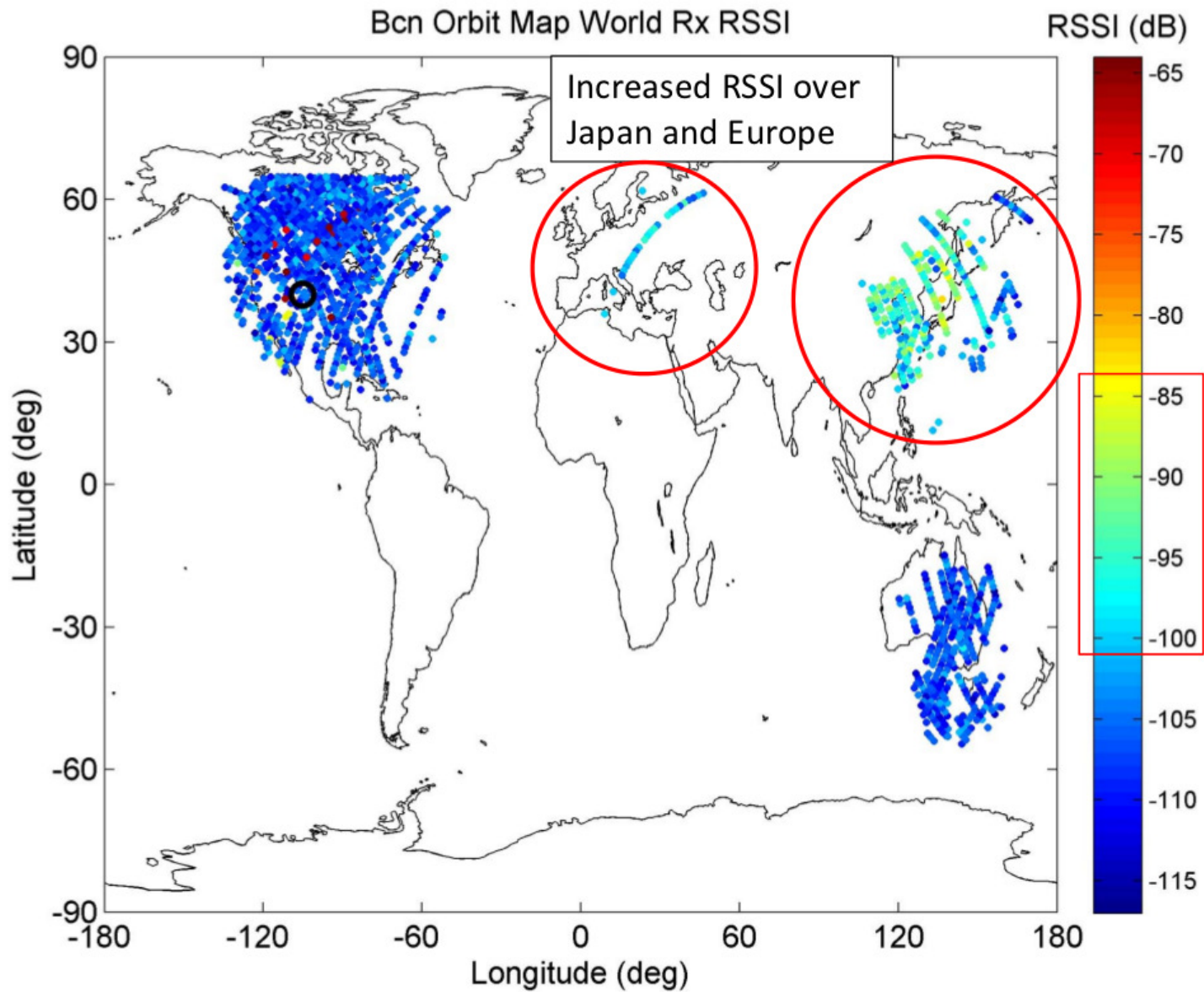
Green = Amateur
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Blue = Non-Amateur
Purple = ISM

Not to scale!

ELaNa-6/NROL-36 CubeSat Launch

- General Issues
 - Object identification is still very difficult; keeps restriction problematic
 - Most satellites healthy and transmitting data
- SMDC-ONE (2):
- AeroCube-4 (3):
- Aeneas: 437.6 MHz packets strong, 437 MHz Microhard
- CSSWE: Science payload turned on, satellite healthy
- CP5: Strong downlink, weak uplink, satellite healthy
- CXBN: Weak downlink, satellite healthy
- CINEMA: Trouble commanding, satellite healthy
- Re: Demonstration of Boeing Colony 2 Bus, several issues being worked. MC3 also being developed/verified

CSSWE RSSI Readings



- Using AstroDev Lithium radio at 437.345 MHz

ISS CubeSat Launch (4 Oct 2012)

- **TechEdSat**
 - NASA Ames & San Jose State University
 - Telemetry at 437.465 MHz
 - Space Plug-n-play demonstration
- **F-1**
 - FPT University in Hanoi, Vietnam
 - 437.485 and 145.980 MHz FM
 - Camera for earth observation
- **FITSat-1**
 - Fukuoka Institute of Technology
 - 437.250 MHz CW, 437.445 MHz FM data
 - 115.2 kbps data at 5840 MHz
 - Camera and LED test
- **WE-WISH**
 - Meisei Amateur Radio Club
 - 437.505 CW and SSTV
 - Infrared camera for earth observation
- **RAIKO**
 - Wakayama and Tohoku University
 - Non-amateur 2.2 GHz and 13 GHz, up to 500 kbps
 - Photography

ISS CubeSat Launch (4 Oct 2012)



Image courtesy of ISS/NASA: ISS033-E-009458 (4 Oct 2012)

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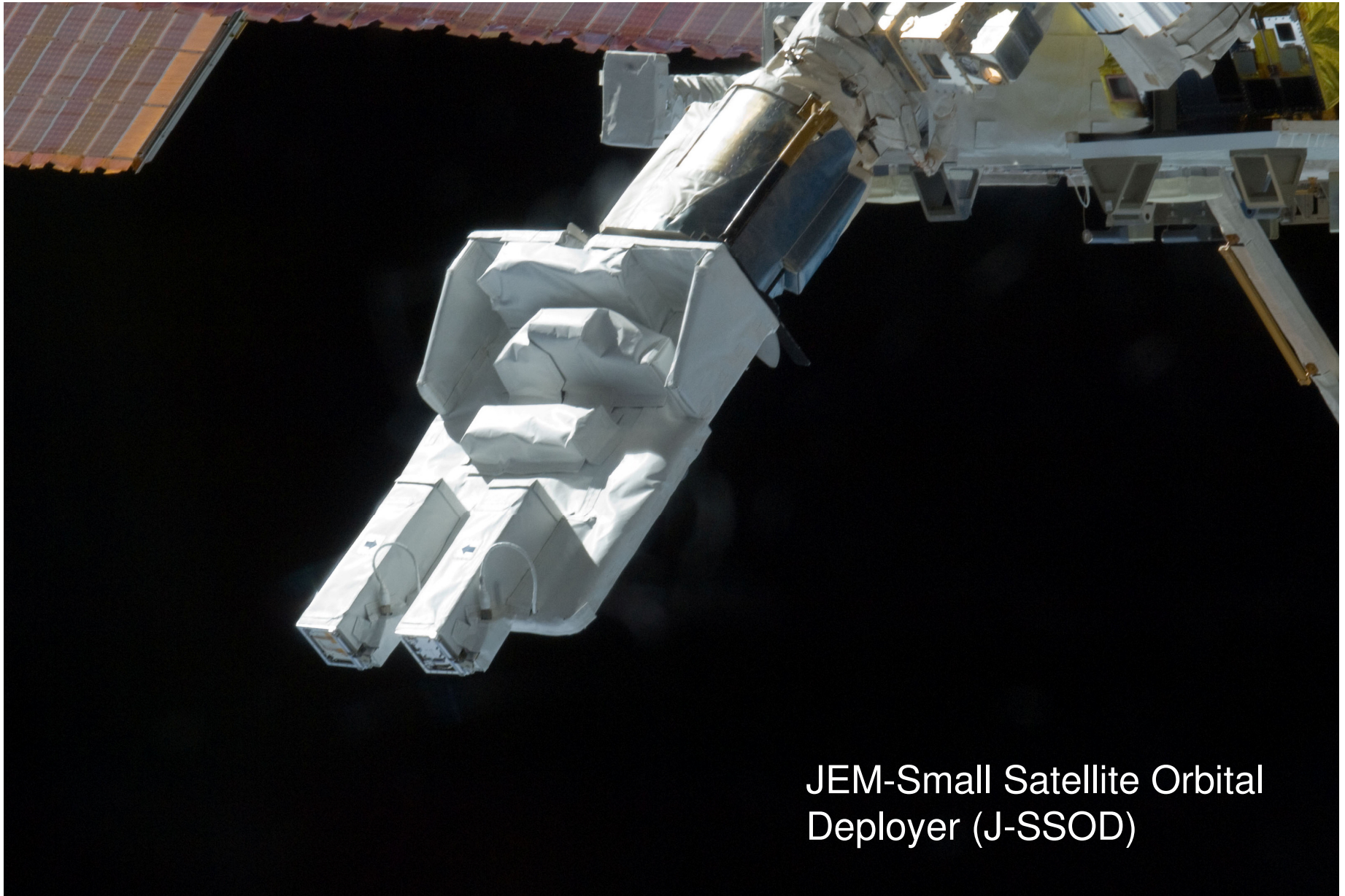
ISS CubeSat Launch (4 Oct 2012)



Image courtesy of ISS/NASA: ISS033-E-009315 (4 Oct 2012)

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ISS CubeSat Launch (4 Oct 2012)



JEM-Small Satellite Orbital
Deployer (J-SSOD)

Image courtesy of ISS/NASA: ISS033-E-009269 (4 Oct 2012)

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Future CubeSat Launches

- Cosmogia DOVE-1
 - Private company
 - Experimental license, 1200 baud AX.25 145.825 MHz StenSat
 - Coordinated through IARU
 - One satellite only; future satellites will use higher frequencies
 - SRI 60-ft dish is supporting higher frequency downlinks

Conclusion

- Low data rate CubeSats will stay with Amateur Radio for the foreseeable future
- Higher data rate CubeSats are transitioning away from Amateur Radio bands
- Special Thanks to:
 - Mike Rupprecht DK3WN for insight into the Vega CubeSats
 - Scott Palo for CSSWE status and RSSI info
 - Giovanni Minelli for Re status
 - Tom Immel for CINEMA status
 - Ben Malphrus for CXBN status

Thank You



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